Article
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Record linkage using InterSystems IRIS, Apache Zeppelin, and Apache Spark

Hi all. We are going to find duplicates in a dataset using Apache Spark Machine Learning algorithms.

Note: I have done the following on Ubuntu 18.04, Python 3.6.5, Zeppelin 0.8.0, Spark 2.1.1

Introduction

In previous articles we have done the following:

- The way to launch Jupyter Notebook + Apache Spark + InterSystems IRIS
- Load a ML model into InterSystems IRIS
- K-Means clustering of the Iris Dataset
- The way to launch Apache Spark + Apache Zeppelin + InterSystems IRIS

In this series of articles, we explore Machine Learning and record linkage.

Imagine that we merged databases of neighboring shops. Most probably there will be records that are very similar to each over. Some records will be of the same person and we call them duplicates. Our purpose is to find duplicates.

Why is this necessary? First of all, to combine data from many different operational source systems into one logical data model, which can then be subsequently fed into a business intelligence system for reporting and analytics. Secondly, to reduce data storage costs. There are some additional use cases.

Approach

What data do we have? Each row contains different anonymized information about one person. There are family names, given names, middle names, date of births, several documents, etc.

The first step is to look at the number of records because we are going to make pairs. The number of pairs equals n*(n-1)/2. So, if you have less than 5000 records, than the number of pairs would be 12.497.500. It is not that many, so we can pair each record. But if you have 50.000, 100.000 or more, the number of pairs more than a billion. This number of pairs is hard to store and work with.

So, if you have a lot of records, it would be a good idea to reduce this number. We will do it by selecting potential duplicates. A potential duplicate is a pair, that might be a duplicate. We will detect them based on several simple conditions. A specific condition might be like:

```
(record1.familyname == record2.familyName) & (record1.givenName == record2.givenName) &
(record1.dateOfBirth == record2.dateOfBirth)
```

but keep in mind that you can miss duplicates because of strict logical conditions. I think the optimal solution is to choose important conditions and use no more than two of them with & operator. But you should convert each feature into one record shape beforehand. For example, there are several ways to store dates: 1985-10-10,

10/10/1985, etc convert to 10-10-1985(month-day-year).

The next step is to label the part of the dataset. We will randomly choose, for example, 5000-10000 pairs (or more, if you are sure that you can label all of them). We will save them to IRIS and label these pairs in Jupyter (Unfortunately, I didn't find an easy and convenient way to do it. Also, you can label them in PySpark console or wherever you want).

After that, we will make a feature vector for each pair. During the labeling process probably you noticed which features are important and what they equal. So, test different approaches to creating feature vectors.

Test different machine learning models. I chose a random forest model because of tests (accuracy/precision/recall/etc). Also, you can try decision trees, Naive Bayes, other classification model and choose the one that will be the best.

Test the result. If you are not satisfied with the result, try to change feature vectors or change a ML model.

Finally, fit all pairs into the model and look at the result.

Implementation

Load a dataset:

```
%pyspark
dataFrame=spark.read.format("com.intersystems.spark").option("url",
"IRIS://localhost:51773/******").option("user", "*******").option("password",
"**********************").option("dbtable", "***************").load()
```

familyName	givenName	middleName	dob	gender	snils	prevIdentityDocuments	fullName	allIdentityDocuments
Мошанова	Рамиля	Ахатовна	1985-04-13	F	337-724-280 89	null	Мошанова^Рамиля^Ахатовна^52698	null
Рыжкова	Анастасия	Станиславовна	1998-02-03	F	135-033-231 07	null	Рыжкова^Анастасия^Станиславовна^57377	null
Шакирзянова	Рамиля	Сергеевна	1979-04-03	F	922-227-272 82	";□□□□□9226□□733988□□□ð □□□□□□□ □A□5□:□>□ □□□K□4□@□5□9□□□""ö","=□□□ □□1591□□544661□□Öä""□□□□□ □□ □A□5□:□>□	Шакирзянова^Рамиля^Сергеевна^50496	null

Clean the dataset. For example, null (check every row) or useless columns:

```
%pyspark
columnstodrop = ['allIdentityDocuments', 'birthCertificatedocSource', 'birthCertificateexpirationDate',
'identityDocumentexpirationDate', 'fullName']
droppedDF = dataFrame.drop(*columnstodrop)
```

Prepare the dataset for making pairs:

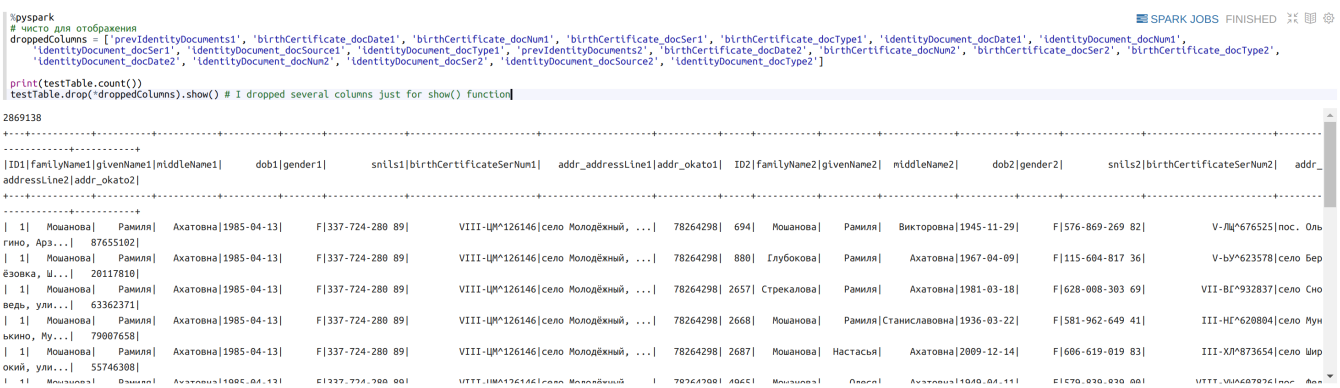
```
%pyspark
from pyspark.sql.functions import col
# rename columns names
replacements1 = {c : c + '1' for c in droppedDF.columns}
df1 = droppedDF.select([col(c).alias(replacements1.get(c, c)) for c in droppedDF.columns])
replacements2 = {c : c + '2' for c in droppedDF.columns}
df2 = droppedDF.select([col(c).alias(replacements2.get(c, c)) for c in droppedDF.columns])
```

To make pairs we will use join function with several conditions.

```
%pyspark
testTable = (df1.join(df2, (df1.ID1 < df2.ID2) & (

  (df1.familyName1 == df2.familyName2) & (df1.givenName1 == df2.givenName2)
 | (df1.familyName1 == df2.familyName2) & (df1.middleName1 == df2.middleName2)
 | (df1.familyName1 == df2.familyName2) & (df1.dob1 == df2.dob2)
 | (df1.familyName1 == df2.familyName2) & (df1.snils1 == df2.snils2)
 | (df1.familyName1 == df2.familyName2) & (df1.addraddressLine1 == df2.addraddressLine2)
 | (df1.familyName1 == df2.familyName2) & (df1.addrokato1 == df2.addrokato2)
 | (df1.givenName1 == df2.givenName2) & (df1.middleName1 == df2.middleName2)
 | (df1.givenName1 == df2.givenName2) & (df1.dob1 == df2.dob2)
 | (df1.givenName1 == df2.givenName2) & (df1.snils1 == df2.snils2)
 | (df1.givenName1 == df2.givenName2) & (df1.addraddressLine1 == df2.addraddressLine2)
 | (df1.givenName1 == df2.givenName2) & (df1.addrokato1 == df2.addrokato2)
 | (df1.middleName1 == df2.middleName2) & (df1.dob1 == df2.dob2)
 | (df1.middleName1 == df2.middleName2) & (df1.snils1 == df2.snils2)
 | (df1.middleName1 == df2.middleName2) & (df1.addraddressLine1 == df2.addraddressLine2)
 | (df1.middleName1 == df2.middleName2) & (df1.addrokato1 == df2.addrokato2)
 | (df1.dob1 == df2.dob2) & (df1.snils1 == df2.snils2)
 | (df1.dob1 == df2.dob2) & (df1.addraddressLine1 == df2.addraddressLine2)
 | (df1.dob1 == df2.dob2) & (df1.addrokato1 == df2.addrokato2)
 | (df1.snils1 == df2.snils2) & (df1.addraddressLine1 == df2.addraddressLine2)
 | (df1.snils1 == df2.snils2) & (df1.addrokato1 == df2.addrokato2)
 | (df1.addraddressLine1 == df2.addraddressLine2) & (df1.addrokato1 == df2.addrokato2)

)))
```

Check the size of returned dataframe:

```
%pyspark
droppedColumns = ['prevIdentityDocuments1', 'birthCertificatedocDate1', 'birthCertificatedocNum1',
'birthCertificatedocSer1', 'birthCertificatedocType1', 'identityDocumentdocDate1',
'identityDocumentdocNum1', 'identityDocumentdocSer1', 'identityDocumentdocSource1',
'identityDocumentdocType1', 'prevIdentityDocuments2', 'birthCertificatedocDate2',
'birthCertificatedocNum2', 'birthCertificatedocSer2', 'birthCertificatedocType2',
'identityDocumentdocDate2', 'identityDocumentdocNum2', 'identityDocumentdocSer2',
'identityDocumentdocSource2', 'identityDocumentdocType2']

print(testTable.count())
testTable.drop(*droppedColumns).show() # I dropped several columns just for show() function
```



Randomly take a part of the dataframe:

```
%pyspark
randomDF = testTable.sample(False, 0.33, 0)
randomDF.write.format("com.intersystems.spark"). \
option("url", "IRIS://localhost:51773/DEDUPL"). \
option("user", "******").option("password", "**********"). \
option("dbtable", "deduplication.unlabeledData").save()
```

Label pairs in Jupyter

Run the following (it will widen the cells).

```
from IPython.core.display import display, HTML
display(HTML("<style>.container { width:100% !important; border-left-width: 1px !important; resize:
vertical}</style>"))
```

Load dataframe:

```
unlabeledDF = spark.read.format("com.intersystems.spark").option("url",
"IRIS://localhost:51773/DEDUPL").option("user", "********").option("password",
"**************").option("dbtable", "deduplication.unlabeledData").load()
```

Return all the elements of the dataset as a list:

```
rows = labelledDF.collect()
```

The convenient way to display pairs:

```
from IPython.display import clearoutput
from prettytable import PrettyTable
from collections import OrderedDict

def printTable(row):
  row = OrderedDict((k, row.asDict()[k]) for k in newColumns)
  table = PrettyTable()
  columnnames = ['Person1', 'Person2']
  column1 = []
  column2 = []
  i = 0
  for key, value in row.items():
  if key != 'ID1' and key != 'ID2' and key != "prevIdentityDocuments1" and key != 'prevIdentityDocuments2'
and key != "features":
  if (i < 20):
  column1.append(value)
  else:
  column2.append(value)
  i += 1
  table.addcolumn(columnnames[0], column1)
  table.addcolumn(columnnames[1], column2)
  print(table)
```

List where we will store rows:

```
listDF = []
```

The labeling process:

```
from pyspark.sql import Row
from IPython.display import clear_output
import time
# 3000 - 4020
for number in range(3000 + len(listDF), len(rows)):
  row = rows[number]
  if (len(listDF) % 10) == 0:
  print(3000 + len(listDF))
  printTable(row)
  result = 0
  label = 123
  while True:
  result = input('duplicate? y|n|stop')
  if (result == 'stop'):
  break
  elif result == 'y':
  label = 1.0
  break
  elif result == 'n':
  label = 0.0
  break
  else:
  print('only y|n|stop')
  continue
  if result == 'stop':
  break
  tmp = row.asDict()
  tmp['label'] = label
  newRow = Row(**tmp)
  listDF.append(newRow)
  time.sleep(0.2)
  clear_output()
```

```
4020
+-----------------------------------------------------+-----------------------------------------------+
|                       Person1                       |                    Person2                    |
+-----------------------------------------------------+-----------------------------------------------+
|                     Водяницкая                      |                  Водяницкая                   |
|                       Олеся                         |                    Олеся                      |
|                     Владимировна                    |                  Владимировна                 |
|                      1959-08-31                     |                   1998-10-02                  |
|                          F                          |                       F                       |
|                    761-103-178 60                   |                  559-442-376 27               |
|                    VII-ЛМ^952287                    |                 III-БС^137900                 |
| пос. Саблуково, улица Никиты Рыбакова, дом 2, кв.26 | пос. Ольгино, улица Краснодонцев, дом 15, кв.36 |
|                      33763996                       |                   52347743                    |
|                      1959-09-08                     |                   1998-10-19                  |
|                        952287                       |                     137900                    |
|                        VII-ЛМ                       |                     III-БС                    |
|                          3                          |                       3                       |
|                      1977-08-26                     |                   2016-09-27                  |
|                        736615                       |                     987609                    |
|                         5184                        |                      3442                     |
|                   ОВД село Широкий                  |                ОВД село Высоково              |
|                          14                         |                       13                      |
+-----------------------------------------------------+-----------------------------------------------+
duplicate? y|n|stopstop
```

Create a dataframe again:

```
newColumns.append('label')
labelledDF = spark.createDataFrame(listDF).select(*newColumns)
```

Save it to IRIS:

```
labeledDF.write.format("com.intersystems.spark").\
option("url", "IRIS://localhost:51773/DEDUPL").\
option("user", "***********").option("password", "**********").\
option("dbtable", "deduplication.labeledData").save()
```

Feature vector and ML model

Load a dataframe into Zeppelin:

```
%pyspark
labeledDF = spark.read.format("com.intersystems.spark").option("url",
"IRIS://localhost:51773/DEDUPL").option("user", "********").option("password", "***********").option("dbtable",
"deduplication.labeledData").load()
```

Feature vector generation:

```
%pyspark
from pyspark.sql.functions import udf, struct
import stringdist
from pyspark.sql.types import StructType, StructField, StringType, IntegerType, DateType, ArrayType,
FloatType, DoubleType, LongType, NullType
from pyspark.ml.linalg import Vectors, VectorUDT
import roman

translateMap = {'A' : 'A', 'B' : 'B', 'C' : 'C', 'E' : 'E', 'H' : 'H', 'K' : 'K', 'M' : 'M', 'O' : 'O', 'P' : 'P', 'T' : 'T', 'X' : 'X', 'Y'
: 'У'}
```

```
columnnames = testTable.drop('ID1').drop('ID2').columns
columnsSize = len(columnnames)//2

def isRoman(numeral):
  numeral = numeral.upper()
  validRomanNumerals = ["M", "D", "C", "L", "X", "V", "I", "(", ")"]
  for letters in numeral:
  if letters not in validRomanNumerals:
  return False
  return True

def differenceVector(params):
  differVector = []
  for i in range(0, 3):
  if params[i] == None or params[columnsSize + i] == None:
  differVector.append(0.0)
  elif params[i] == 'HET' or params[columnsSize + i] == 'HET':
  differVector.append(0.0)
  elif params[i][:params[columnsSize + i].find('-')] == params[columnsSize + i][:params[columnsSize +
i].find('-')] or params[i][:params[i].find('-')] == params[columnsSize + i][:params[i].find('-')]:
  differVector.append(0.0)
  else:
  differVector.append(stringdist.levenshtein(params[i], params[columnsSize+i]))
  for i in range(3, columnsSize):
  # snils
  if i == 5 or i == columnsSize + 5:
  if params[i] == None or params[columnsSize + i] == None or params[i].find('123-456-789') != -1 or
params[i].find('111-111-111') != -1 \
  or params[columnsSize + i].find('123-456-789') != -1 or params[columnsSize + i].find('111-111-111') != -1:
  differVector.append(0.0)
  else:
  differVector.append(float(params[i] != params[columnsSize + i]))
  # birthCertificatedocNum
  elif i == 10 or i == columnsSize + 10:
  if params[i] == None or params[columnsSize + i] == None or params[i].find('000000') != -1 or
params[i].find('000000') != -1 \
  or params[columnsSize + i].find('000000') != -1 or params[columnsSize + i].find('000000') != -1:
  differVector.append(0.0)
  else:
  differVector.append(float(params[i] != params[columnsSize + i]))
  # birthCertificatedocSer
  elif i == 11 or i == columnsSize + 11:
  if params[i] == None or params[columnsSize + i] == None:
  differVector.append(0.0)
  # check if roman or not, then convert if roman
  else:
  docSer1 = params[i]
  docSer2 = params[columnsSize + i]
  if isRoman(params[i][:params[i].index('-')]):
  docSer1 = str(roman.fromRoman(params[i][:params[i].index('-')]))
  secPart1 = '-'
  for elem in params[i][params[i].index('-') + 1:]:
  if 65 <= ord(elem) <= 90:
  secPart1 += translateMap[elem]
  else:
  secPart1 = params[i][params[i].index('-'):]
  docSer1 += secPart1
  if isRoman(params[columnsSize + i][:params[columnsSize + i].index('-')]):
  docSer2 = str(roman.fromRoman(params[columnsSize + i][:params[columnsSize + i].index('-')]))
```

```
    secPart2 = '-'
    for elem in params[columnsSize + i][params[columnsSize + i].index('-') + 1:]:
    if 65 <= ord(elem) <= 90:
    secPart2 += translateMap[elem]
    else:
    secPart2 = params[columnsSize + i][params[columnsSize + i].index('-'):]
    break
    docSer2 += secPart2
    differVector.append(float(docSer1 != docSer2))
    elif params[i] == 0 or params[columnsSize + i] == 0:
    differVector.append(0.0)
    elif params[i] == None or params[columnsSize + i] == None:
    differVector.append(0.0)
    else:
    differVector.append(float(params[i] != params[columnsSize + i]))
    return differVector

featuresGenerator = udf(lambda input: Vectors.dense(differenceVector(input)), VectorUDT())


%pyspark
newTestTable = testTable.withColumn('features', featuresGenerator(struct(*columnnames))) # all pairs
df = df.withColumn('features', featuresGenerator(struct(*columnnames))) # labeled pairs
```

Split labeled dataframe into training and test dataframes:

```
%pyspark
from pyspark.ml import Pipeline
from pyspark.ml.classification import RandomForestClassifier
from pyspark.ml.feature import IndexToString, StringIndexer, VectorIndexer
from pyspark.ml.evaluation import MulticlassClassificationEvaluator

# split labelled data into two sets
(trainingData, testData) = df.randomSplit([0.7, 0.3])
```

Train a RF model:

```
%pyspark
from pyspark.ml.classification import RandomForestClassifier

rf = RandomForestClassifier(labelCol='label', featuresCol='features')

pipeline = Pipeline(stages=[rf])

model = pipeline.fit(trainingData)

# Make predictions.
predictions = model.transform(testData)
# predictions.select("predictedLabel", "label", "features").show(5)
```

Test the RF model:

```
%pyspark
```

```
TP = int(predictions.select("label", "prediction").where((col("label") == 1) & (col('prediction') == 1)).count())
TN = int(predictions.select("label", "prediction").where((col("label") == 0) & (col('prediction') == 0)).count())
FP = int(predictions.select("label", "prediction").where((col("label") == 0) & (col('prediction') == 1)).count())
FN = int(predictions.select("label", "prediction").where((col("label") == 1) & (col('prediction') == 0)).count())
total = int(predictions.select("label").count())

print("accuracy = %f" % ((TP + TN) / total))
print("precision = %f" % (TP/ (TP + FP)))
print("recall = %f" % (TP / (TP + FN))
```

How it looks:

```
%pyspark
z.show(predictions.where((col('label') == 1) & (col('prediction') == 1)).drop(*droppedColumns))
```

SPARK JOBS FINISHED

settings

snils2	birthCertificateSerNum2	addr_addressLine2	addr_okato2	label	features	rawPrediction	probability	prediction
01-587-304 89	IX-ЭЗ^545879	пос. Верхняя Верея, улица Репина, дом 37, кв.46	61011318	1	[0.0,1.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0]	[2.466887417218543, 17.533112582781456]	[0.12334437086092716,0.8766556291390728]	1
42-784-557 10	II-ЦП^800383	пос. Таремское, улица 5 Декабря, дом 17, кв.16	18137773	1	[1.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0]	[1.466887417218543, 18.533112582781456]	[0.07334437086092715,0.9266556291390728]	1

Use the RF model on all the pairs:

```
%pyspark
allData = model.transform(newTestTable)
```

Check how many duplicates are found:

```
%pyspark
allData.where(col('prediction') == 1).count()
```

```
%pyspark
allData.where(col('prediction') == 1).count()
```

```
116
```

Or look at the dataframe:

```
%pyspark
z.show(allData.drop(*droppedColumns))
```

SPARK JOB FINISHED

settings

gender2	snils2	birthCertificateSerNum2	addr_addressLine2	addr_okato2	features	rawPrediction	probability	prediction
	199-233-382 08	VII-ЛТ^316118	пос. Хвощёвка, Радиальная улица, дом 4, кв.100	34980950	[0.0,0.0,0.0,1.0,0.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,0.0,1.0,1.0,1.0,1.0,1.0,1.0]	[20.0,0.0]	[1.0,0.0]	0
	636-891-255 36	VI-ОЦ^426746	село Волчиха, улица Бренциса, дом 39, кв.16	17256070	[0.0,0.0,0.0,1.0,0.0,1.0,0.0,1.0,1.0,1.0,1.0,1.0,0.0,1.0,1.0,1.0,1.0,1.0,1.0]	[20.0,0.0]	[1.0,0.0]	0
	920-073-633 70	VII-ДЫ^348149	пос. Хохлома, переулок Титова, дом 17, кв.33	27547771	[0.0,0.0,0.0,1.0,0.0,1.0,0.0,1.0,1.0,1.0,1.0,1.0,0.0,1.0,1.0,1.0,1.0,1.0,1.0,	[20.0,0.0]	[1.0,0.0]	0

Conclusion

This approach is not ideal. You can make it better by experimenting with feature vectors, a model or increasing the size of labeled dataset.

Also, you can do the same to find duplicates, for example, in shops database, historical research, etc...

Links

- Apache Zeppelin
- Jupyter Notebook
- Apache Spark
- Record Linkage
- ML models
- The way to launch Jupyter Notebook + Apache Spark + InterSystems IRIS
- Load a ML model into InterSystems IRIS
- K-Means clustering of the Iris Dataset
- The way to launch Apache Spark + Apache Zeppelin + InterSystems IRIS
- GitHub

#Artificial Intelligence (AI) #Analytics #Beginner #Machine Learning (ML) #Python #Vector Search #InterSystems IRIS